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Combining weighted daily life circles and land suitability for rural settlement reconstruction

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ABSTRACT

Daily life circles of farmers have a direct influence on the distribution of rural settlements. However, daily life circle has long been ignored in rural settlements reconstruction. By identifying farmers' daily life circles and integrating them with rural settlements suitability and the weighted Voronoi diagram, a rural settlement reconstruction method is developed based on a questionnaire survey in Liji Township, Hubei Province, Central China. Four types of daily life circles, including primary, general, extended, and cross-region daily life circles, are identified based on the evaluation of frequency, self-rated importance, and activity proportion. Combining with the analysis of the rural settlements' suitability and the weighted Voronoi diagram, two reconstruction directions for rural settlement relocation are offered. One direction is to the places with high suitability values within the administrative scope of a village where the removed settlements are located. The other direction is to the places with high suitability values within the weighted daily life circles; this direction is highly related to the removed settlements. The hierarchy of rural settlements planning is well reflected in the proposed reconstruction path. Farmers' willingness to participate in the reconstruction process could be improved based on the evaluation of suitability and their own demands in daily life activities. This study contributes to understanding the relationship between the daily life circles and rural settlement distribution and offers a new perspective on the spatial optimization of rural settlements.

1. Introduction

Rapid urbanization has brought the prosperity of urban economics and the growth of urban space, but it has also led to a global rural recession (Dax & Fischer, 2018; Liu & Li, 2017). Rural China has been undergoing an unprecedented recession in the past decades. A series of issues, including rural population loss and rural hollowing, are increasing serious (Liu, Liu, Chen, & Long, 2010; Tan, Li, Xie, & Lu, 2005; Wang, Hui, & Sun, 2017; Yang, Liu, Long, & Qiao, 2015). To revitalize rural development, China's central government implemented a project for building a new countryside in 2005. It aims to improve production and livelihood, build clean and tidy villages, and develop a civilized social atmosphere and efficient management (He, 2007). However, a conflict exists between the stress of maintaining a total of 120 million ha of arable land to ensure food security and the demand for land for urbanization and rural development (Ge, Long, Zhang, Ma, & Li, 2018). Facing the plight of a large floating population and the disorderly construction of rural settlements, there is a rising call for rural reconstruction (Long & Liu, 2016; Wang et al., 2017).

Spatial optimization of rural settlements is one of the most important parts of rural reconstruction and has been adopted widely in solving problems appearing in rural development (Li, Liu, Long, & Cui, 2014; Tian, Liu, Liu, Kong, & Liu, 2017). Existing studies usually consolidate rural residential land from two perspectives. One perspective is quantitative structural optimization, and the other is spatial optimization. Quantitative optimization focuses on the estimation of the potential and the readjustment of the quantitative structure of rural residential land (Liu, Kong et al., 2013; Liu, Yang et al., 2013). Spatial optimization emphasizes reorganization of the spatial distribution of rural settlements by exploring different modes. The main methods in this field can be summarized as the following: 1) Comprehensive evaluation. Social, economic, and natural factors are commonly adopted to develop a comprehensive evaluation index system. Rural settlements located in underdeveloped areas are advised to relocate to areas with a better development level (Guo, Liao, & Xu, 2012; Tian, Kong, Liu, & Wang, 2016; Zhu, Wang, Yuan, & Hou, 2010). 2) Accessibility evaluation. The accessibility of certain facilities or services is determined, and rural settlements with poor access to such facilities or services are

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Table 1
Early application of daily life circle.

Related concept	Derivation	Explanation
Primary zones	*New Comprehensive National Development Plan of Japan* (1969)	Create a comprehensive environment with diverse functions for human beings[a]
Stable settlement	The 3rd *Comprehensive National Development Plan of Japan* (1977)	Zones are connected by transportation and communication, to satisfy people's life demands
Metropolitan daily life circle	*Capital Circle Planning of Seoul* (South Korea, 1982)	Control population inflow to metropolitan areas by distributing functions on spaces
Regional daily life circle	*Comprehensive Development Plan of Taiwan* (1996)	Develop areas to satisfy local residents' basic daily life demands

[a] "The land will be reorganized by making broad activity zones as primary zones at the motorized stage … The regional hub city of each zone will be improved to create the agglomeration of urban functions at the appropriate level." https://eric.ed.gov/?id=ED062232, page 24.

advised to relocate (Linard, Gilbert, Snow, Noor, & Tatem, 2012; Liu, Cui et al., 2016; Liu, Fan et al., 2015; Liu, Ye et al., 2016; Liu, Yuan et al., 2015). 3) Scenario simulation. Future scenes of rural settlements are achieved using models such as cellular automaton, ant colony algorithm, and genetic algorithm with multi-objective decisions. Relocation strategies can be developed based on the simulation results (Liu, Fan et al., 2015; Liu, Kong et al., 2013; Liu, Yang et al., 2013; Liu, Yuan et al., 2015; Porta et al., 2013; Sang, Zhang, Yang, Zhu, & Yun, 2011).

The concept of daily life circle was originated from Japan. Table 1 shows early application of daily life circle. It focuses on the travel behavior of local residents and routines to extract the areas with different service functions to satisfy the daily life demands of the local residents (Algers, Eliasson, & Mattsson, 2005; Fan & Khattak, 2008; Healey, 2004; Krizek, 2003; Zhang, 2005). Since then, daily life circle has been widely used in urban planning and construction. It well describes the daily life situation of the people from the perspective of daily activities, and it also well reflects the relationship between people and their daily living environments. Rural settlements offer stable habitation for residents to conduct their daily life activities. Correspondingly, the residents' daily lives have effects on the distribution of rural settlements. Such relationships between residents and their daily living environments have been proven to have effects on their choice of residence (Aitken & Fik, 1988; Brun & Fagnani, 1994; Prillwitz, Harms, & Lanzendorf, 2007; Wang, Li, & Chai, 2012). However, the relationships between residents and their daily living environments are rarely considered in spatial optimization of rural settlements. To fill the gap in current studies, we proposed a spatial optimization method for rural settlements based on the identification of daily life circles.

Land suitability is an important standard for rural settlement distribution. The existing studies usually developed an evaluation index system for land suitability based on multiple indicators, including social, economic, and natural factors, and the evaluated area is usually classified into different levels based on the evaluation values (Liu et al., 2007; Mokarram & Aminzadeh, 2010; Xu, Kong, Li, Zhang, & Wu, 2011). Rural settlements with low suitability values are potential objectives to be removed, and areas with high suitability values may potentially be arranged as new rural settlements. However, farmers have different preferences in choosing villages to visit or to conduct activities in their daily lives; such preferences reflect the relationship between farmers and their living environments and in turn have effects on their willingness for rural settlement relocation. Therefore, it is important to integrate the daily life circle elements into the evaluation index system of rural settlement suitability to improve the habitat satisfaction of farmers.

Although the suitability of rural settlement provides important information for rural settlement optimization, the suitable relocation areas related to the removed settlements are difficult to identify in a town or a village, which need to be further divided spatially according to regional differentiation. To address this issue, the weighted Voronoi diagram was introduced into rural settlement optimization. The weighted Voronoi diagram is a developed form of the Voronoi diagram and is commonly used to study the area of influence of places in urban studies (Boots & South, 1997; Mu, 2004). The partitions of the weighted Voronoi diagram not only consider the effects of different villages but also break through the limits of administrative scope. The weights of generator points to develop the weighted Voronoi diagram are usually obtained based on a comprehensive evaluation of the influence power of points, which usually includes factors such as population, serving ability, and economic development level (Ohyama, 2005; Oliveira, Gonalves, de Cursi, & Novaes, 2008; Wang, Lu, Ge, & Wang, 2014).

Rural settlements reconstruction should focus on satisfying the daily life needs of farmers, which has been ignored in current studies. This paper proposed a method to identify daily life circles based on a questionnaire survey in Liji Township, Hubei Province, Central China. We integrated daily life circles into suitability evaluation of rural settlements and weighted Voronoi diagram analysis to optimize spatial distribution of rural settlements. The goals of this study are to address three pressing issues: 1) How to identify daily life circles at village level? 2) Which activities are highly related to different daily life circles? 3) How to indicate the optimization direction of rural settlements to reflect the needs of farmers and the spatial needs of settlements?

2. Study area and data

Liji Town (114°08′ to 114°18′E, 31°09′ to 31°57′N), located in Huangpi District, is in the northern region of Wuhan, Hubei Province of central China (Fig. 1). Liji has 53 administrative villages. The total area of rural settlements of Liji is 1324.73 ha, and its per capita area is 182.63 m^2, which is higher than the national highest average of 150 m^2. According to the questionnaire investigation conducted in Liji in 2015, the rural-urban migration rate is 21.62%, which indicates serious problems in hollowed villages and inefficient utilization of rural settlements in Liji. The government of Liji has implemented some land consolidations projects to improve rural living environments in recent years. However, how to guide rural settlement reconstruction in an orderly manner to satisfy the daily life needs of farmers is still a challenge for the local government.

A total of 1820 people participated in a face-to-face survey in 2015. The valid usable return rate was 85.88% with valid returns of 1563. The questions included the basic attributes of respondents such as age, education level, occupation type, annual income, number of family members, and marital status. Information about individual daily activities was also included, such as "Where do you often go in Liji township?", "What type of activities do you do there?", and "To what extent do you think the activity is important?". Questions such as "What do you think is the most serious problem concerning you?" and "Are you willing to relocate?" were also asked. Table 2 shows the basic characteristics of the 1563 respondents.

Two main stages were included in the sampling process to ensure that the survey data were representative. All 423 patches of rural settlements in Liji Town were numbered, and a total of 200 of them were surveyed. The largest patch in each of the 53 villages was surveyed in priority, and the remainder of the 147 were chosen through random sampling. The questionnaire was administered in proportion to the population of the village and its patch size. Statistical data used in the